Outline



- Background and objectives
- Nozzle overview and ground test results
- Flight test approach and pilot-vehicle interface
- Flight test execution and results
- Concluding remarks

This section presents an overview of the vectoring system and results from the ground demonstration testing of the nozzle in preparation for flight.

P/Y BBN Overview Convergent actuator F100 Balanced Beam Nozzle Throat area (A8)Exit area Gas path (A9) **Fulcrum** load Divergent flap Cooling Convergent flap air load 1 BI External flap Cooling load Path load Minimal Balance flap actuation force Augmentor Fulcrum required

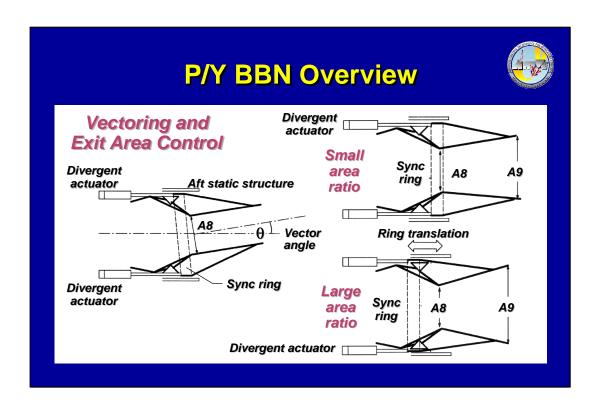
The left-hand side of this slide shows the major components of the F100 pitch-yaw balanced beam vectoring nozzle (PYBBN). The right-hand side presents a detail of the balanced-beam feature that gives the nozzle its name. Pressurized cooling air from the fan discharge balances the loads on the convergent flaps exposed to the gas path exiting the augmentor. This load balancing minimizes the forces required for convergent section actuation and allows for a lighter weight actuation system that has, as a result, inherent growth potential.

P/Y BBN Overview P/Y BBN adds: Multi-axis thrust vectoring Exit area control with only 3 functional changes to basic F100-PW-229 BBN Static structure Convergent actuator Divergent sync ring Divergent seal Convergent sync ring Divergent flap P/Y BBN External flap/ vectoring mechanism Divergent actuator Aft static structure

Only three functional changes are required to give the bill-of-material F100 nozzle vectoring and exit area control capability. The first is the divergent sync ring that positions the divergent flap and seals. The static structure that supports the sync ring is the second functional change. The static structure is designed to allow the sync ring to smoothly translate and rotate, permitting simultaneous vectoring and exit area modulation. The third functional change is the addition of hydraulically-driven divergent actuators which attach to, and position, the sync ring.

The number of convergent actuators, relative to the bill-of-material nozzle, has been reduced, and there are actually fewer parts in the vectoring nozzle than in the bill-of-material nozzle.

Few modifications were required to the engine forward of the nozzle in order to support the vectoring capability. These were limited to minor changes to external hardware on the augmentor duct in the vicinity of the nozzle, along with thicker fan and augmentor ducts required to absorb the off-axis vectoring loads imparted by the nozzle.



The nozzle controller vectors the divergent section by differentially positioning the three divergent actuators (left side of slide). The sync ring in the divergent section positions the proper commanded angle.

Nozzle exit area (A9) is positioned independent of the throat area (A8). Independent positioning of the nozzle exit area allows for higher nozzle performance in some parts of the envelope by reducing flow-related losses.

P/Y BBN Overview



- Redundancy is key to fullenvelope application
 - Fail-operational/fail-safe configuration increases safety
 - Independent divergent and convergent actuation systems maximize system safety

Dual hydraulics



Dual electronics

Production-Design Pitch/Yaw Balanced Beam Nozzle Module

The PYBBN hydraulic and electrical systems, as well as the nozzle controller, are dual-redundant, allowing the nozzle to be used in flight-critical applications.

Because of system redundancy, most system failures, including bus, sensor, and computer channel failures, result in full fail-op capability. In the event that the nozzle controller is not able to maintain adequate control of the system, it places the divergent section into a fail-safe mode, in which the divergent actuators are hydraulically locked and electrically isolated.

As in the bill-of-material system, the nozzle convergent section (throat) is controlled by the digital engine controller. This de-coupling from the nozzle controller, which only positions the divergent section, provides for full engine capability even in the event of a vectoring system anomaly that places the divergent section in a fail-safe mode. Engine operation and control is not degraded in any way.

Next, I'll show a video highlighting the results of the ground testing of the vectoring nozzles in preparation for the ACTIVE flight program.